July 18, 2003

To: HST-JWST Transition Plan Review Panel

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Subject: Relation of SIRTF to the HST-JWST Transition

Executive Summary: SIRTF will be launched in August 2003. SIRTF's capabilities in the 3.6-30_m band make it an important scientific precursor to JWST under all circumstances. SIRTF's lifetime is such that it could be operating into the 2010 time frame or beyond and thus help to fill the gap between the (planned or premature) cessation of HST and the initiation of JWST observations. Accurate projections of the expected cryogenic lifetime of SIRTF and of the performance of SIRTF in a post-cryogen "lukewarm" mode should be available in mid-2004.

SIRTF Overview:

1. **Measurement Capabilities:** SIRTF provides imaging with 5x5 arcmin fields of view in 6 bands (3.6, 4.5, 5.8, 8.0, 24 and 70 _m) and a 1.5x5 arcmin field for imaging at 160 _m and spectroscopy with resolution R=60 from 5-40 _m and R=600 from 10-40 _m. SIRTF's ~0.5 sq. meter collecting area makes it a factor of ~50 less sensitive than JWST, but over most of its wavelength range SIRTF is at least a factor of ~50 times more powerful than any previous facility. Thus SIRTF is an essential scientific precursor to JWST at all wavelengths longward of the NICMOS/HST cutoff at 2.5 _m.

2. **Cryogenic Lifetime**: SIRTF's cryo-thermal system uses a combination of radiative and vapor cooling which is difficult to test completely on the ground. The required cryogenic lifetime is 2.5 yrs. The current best estimate of the cryogenic lifetime which will be achieved on orbit, based on extensive pre-launch testing and both thermal and operational modeling, is 5.6 yrs.

3. **Lukewarm Mission:** At the point of cryogen exhaustion SIRTF will be ~0.6 AU from the Earth, drifting away in its earth-trailing solar orbit at ~ 0.1 AU/yr. The radiative cooling will still be in effect, and we project that the telescope and instruments will warm up only to about 30K. At this temperature, the two shortest wavelength imaging bands of the IRAC at 3.6 and 4.5_m should continue to operate without degradation.

4. **Ultimate Lifetime:** At the end of 10 years, the Earth-Sun-SIRTF geometry will be such that transmitting data with the body-fixed antenna will not be possible within the nominal range of solar incidence angles on the solar panels. Other than the cryogen, the only consumable on SIRTF is the reaction control system

gas, which is predicted to last considerably longer than five years. The spacecraft incorporates high heritage avionics and is fully redundant, and both the spacecraft and the payload have a minimum of moving parts. Thus it is plausible that SIRTF could remain operable to 2010 or beyond.

SIRTF in the context of the HST-JWST transition.

To respond more sharply to the issues raised in the charge to the panel, we consider three scenarios consistent with the current HST-JWST transition plan.

a. **Premature loss of some or all of the capabilities of HST**. Because of SIRTF's unique capabilities as a scientific precursor to JWST, a premature loss of some or all of the capabilities of HST need not lead to a proportionate loss in the ability of the community to prepare scientifically for JWST.
b. **The nominal transition plan**. It is plausible that SIRTF could be operating in the lukewarm mode in the 2010 time frame when HST operations cease in the nominal plan. SIRTF could then provide scientific and programmatic continuity between HST and JWST. Under these circumstances, SIRTF could be used, for example, for deep, wide field surveys at 3.6 and 4.5um which might pinpoint promising targets for spectroscopic or imaging followup with JWST.
c. **Possible delays in JWST**. The above considerations would also apply in the case of delays in the JWST beyond the projected 2011 launch, although operation of SIRTF in this time frame implies increasingly more optimistic predictions of its lifetime.

The SIRTF timescale.

The ability of SIRTF to address the scenarios discussed above depends in detail both on the cryogenic lifetime of SIRTF and the viability of the lukewarm mission. These in turn depend on the on-orbit cryo-thermal performance of SIRTF, which should be pretty well understood by mid 2004 on the current schedule. At that time, it should be possible to define more sharply SIRTF's potential role[s] in the HST-JSWT transition

SIRTF as a scientific precursor to JWST. The JWST spectral band runs from 0.6 to 27 _m. HST operates from 0.1 to 2.5 _m, while SIRTF operates from 3.6 to 160 _m. Clearly both HST and SIRTF have unique capabilities for studying scientific targets and defining scientific questions which will lay the groundwork for further observations with JWST, but, beyond 3 _m, SIRTF offers the closest approach in sensitivity to JWST of any existing platform, space- or ground-based. *We emphasize that SIRTF's role as a essential scientific precursor to JWST remains valid in any scenario for the HST-JWST transition, including the contingencies addressed above.*

The scientific themes that SIRTF will address are intimately related to JWST science. Currently we have in place ~1 year of science observations, approximately half of which comprise the SIRTF Legacy Science program, and the other half represents the science programs submitted from the SIRTF Guaranteed Time Observers (GTOs - Instrument teams and Science Working Group members). The principal science themes embodied in these programs are in general terms the formation and evolution of galaxies in the distant universe, and the formation and evolution of stars and planetary systems in our own Galaxy.

The SIRTF extragalactic programs include wide field (many tens of square degrees) surveys at all the SIRTF imaging wavelengths to sensitivities of factors of 10 to 1000 deeper than any other platform has ever achieved. In addition, SIRTF observations over small fields will reach even deeper, to the confusion limit set by the telescope diameter. A highlight SIRTF program in this area is the Great Observatory Origins Deep Survey (GOODS), a project that reaches the deepest possible observations in the same fields with all of NASA's Great Observatories (Chandra, HST & SIRTF). Figure 1 shows the fields of the GOODs program and how the combination of HST and SIRTF observations can be used, while figure 2 shows the depths we expect to reach with our SIRTF surveys compared to the expected performance of limiting JWST surveys

The SIRTF extragalactic surveys will provide publicly available datasets that the entire astronomical community can exploit for many years, both to guide follow-on SIRTF observations and to prepare for JWST programs. A major follow-on to the SIRTF extragalactic surveys, already planned within the GTO programs and certain to continue with the General Observers, is observations with the Infrared Spectrometer of targets found in the surveys. These observations will establish the character (powered by accretion or star formation) and redshifts of the infrared luminous systems that comprise the dominant fraction of the far infrared background radiation.

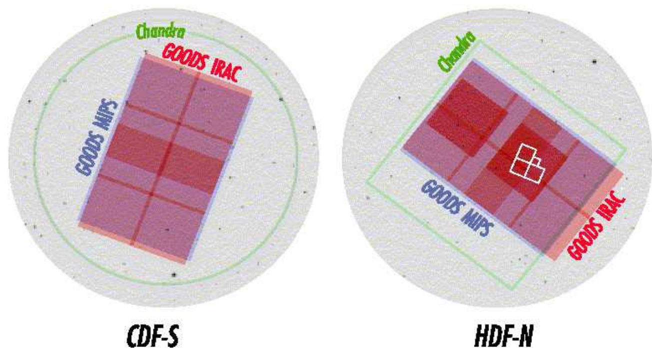
In the field of galactic science SIRTF will place heavy emphasis on tracing the formation and evolution of planetary systems from the nascent stages in molecular clouds through the highly evolved planetary debris phase. These programs include surveys of ~30 square degrees in molecular clouds to identify the earliest stages of forming stars and brown dwarfs, through detailed observations of planetary debris systems ranging up to the age of our own solar system. Figure 3 illustrates a typical molecular cloud being covered by a SIRTF survey, while figure 4 shows how a protoplanetary disk might evolve, leaving behind the debris of stellar and planetary formation, and how SIRTF observations might trace the evolution of such systems.

The science programs we described above will occupy a healthy fraction of the first year of the SIRTF science mission. The first post launch opportunity for the astronomical community to propose for SIRTF observations (referred to as Cycle 1) will occur with a proposal due date of Launch + 5 months, and we will begin executing the program selected in Cycle 1 at launch + 9 months (Launch of SIRTF is scheduled for 23 August). The SIRTF Legacy program has been developed with no PI proprietary period to enable the entire astronomical community to utilize major portions of SIRTF data as soon as they become available to the Legacy teams. These data will be available for the community to utilize in their SIRTF programs starting with Cycle 2. Proposals for Cycle 2 will be due at launch + 16 months. Altogether, six Legacy teams were selected competitively and awarded a total of 3160 hours of observing time [see http://sirtf.caltech.edu/SSC/ for more detailed information on the SIRTF Legacy program and other aspects of SIRTF]; the SIRTF GTOs are receiving a comparable amount of observing time and carrying out a wide range of investigations on various scales, many of which dovetail very well with the Legacy programs.

The general astronomical community – which will receive >75% of the observing time on SIRTF through the usual peer-reviewed proposal process - will have great opportunities to exploit the unique observational capabilities afforded by SIRTF, and we firmly believe that the SIRTF observations will have major impacts on the JWST science mission: Results from both SIRTF and HST, combined with scientific progress in other areas, will inevitably shape the approach taken by JWST to the study of its major defining scientific themes. In addition, within the next decade JWST will be the only platform available to follow-up on SIRTF discoveries with yet higher sensitivity - coupled with improved spatial resolution and/or higher resolution spectroscopy - over the wavelength range 3-30_m.

Historically the interplay between NASA's missions has been highly beneficial to the advancement of astronomy. The astronomical community is keenly aware of the importance of multi-wavelength observational studies. The GOODS project, which exploits enormous observational efforts on the part of HST, Chandra and soon SIRTF, is an example of how to utilize NASA's Great Observatories for the expansion of our understanding of the early universe. We are confident that the synergy between SIRTF, Chandra and Hubble, and in the future between SIRTF and JWST, will achieve major new discoveries and improvements in our view of the universe

FIGURES



Great Observatories Synergy.

Figure 1a (SIRTF GOODS Legacy Team – M. Dickinson PI)

The deepest observations currently planned for SIRTF will be obtained by the Great Observatories Origins Deep Survey (GOODS) Legacy project. The targets of these observations are the Hubble Deep Field North (HDF-N) and Chandra Deep Field South (CDF-S). Both regions have received more than one million second exposures with the ACIS camera on Chandra (green outlines), which has a 16 arcminute FOV. Because the CDF-S data were obtained at a variety of position angles, the Chandra coverage here is shown as a circle. The SIRTF observations are the red shaded areas. The CDF-S is also the target of the upcoming HST-ACS Ultradeep field. The region covered by the existing WFPC2 HDF-N data is outlined in white. The performance achievable in these long integrations is shown in Figure 2.

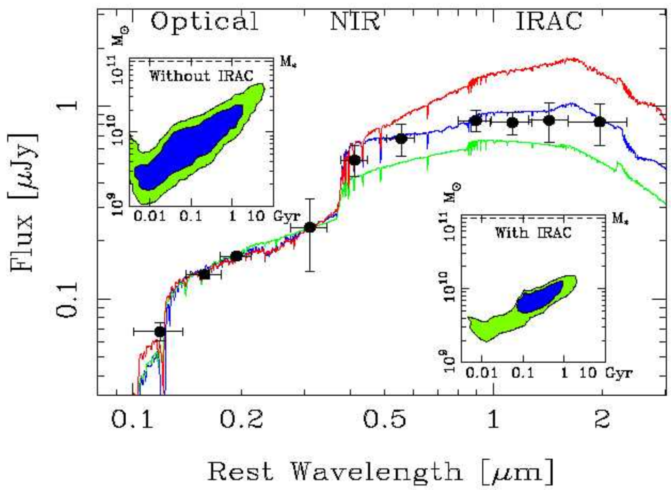


Figure 1b (SIRTF GOODS Legacy Team – M. Dickinson PI)

Plot illustrating the importance of SIRTF observations in constraining the mass and age of a distant galaxy such as might be observed in the GOODS fields. This represents a simulation of optical, near infrared and SIRTF 3-8_m (IRAC) observations of a galaxy at z~3. The red, blue and green lines show acceptable model fits to the observations without the SIRTF data (rest wavelengths below 0.6 _m). Including the SIRTF data restricts acceptable models to only the blue line. The range of allowable masses and ages for this system with and without the SIRTF data are shown in the insert panels (blue area - 68% confidence fits, green area – 95% confidence fits).

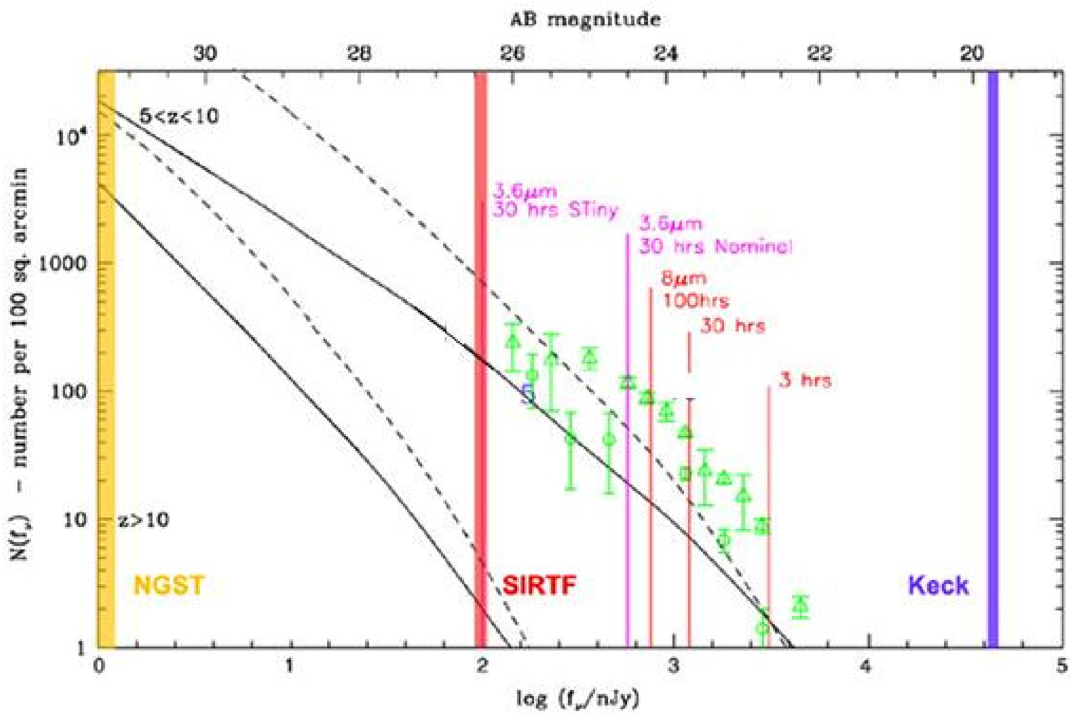


Figure 2. (SIRTF GOODS Legacy Team – M. Dickinson PI)

Illustrating that SIRTF sensitivity at 3.6_m is intermediate between that of Keck (for a 10,000 second observation at 3.2_m) and that projected for JWST (NGST) at 3_m (for a 100,000 second observation); with possible source count models superposed. The vertical lines show sensitivity achievable from SIRTF at 3.6 and 8_m for a range of integration times and (at 3.6 _m) two choices of on-orbit image quality - the actual performance should lie between these limits. The SIRTF sensitivity for deep imaging is limited at all wavelengths by the confusion limit of the telescope. The green triangles and circles are the observed [optically] density of galaxies in the range 2.6<z<3.4 and 3.8<z<4.5, respectively, converted to IRAC fluxes using a spectra energy distribution model for a Luminous Blue Galaxy. The solid and dashed lines are models of surface densities of quasars (solid lines) and galaxies (dashed lines) in the redshift ranges 5<z<10 (upper lines) and z>10 (lower lines).

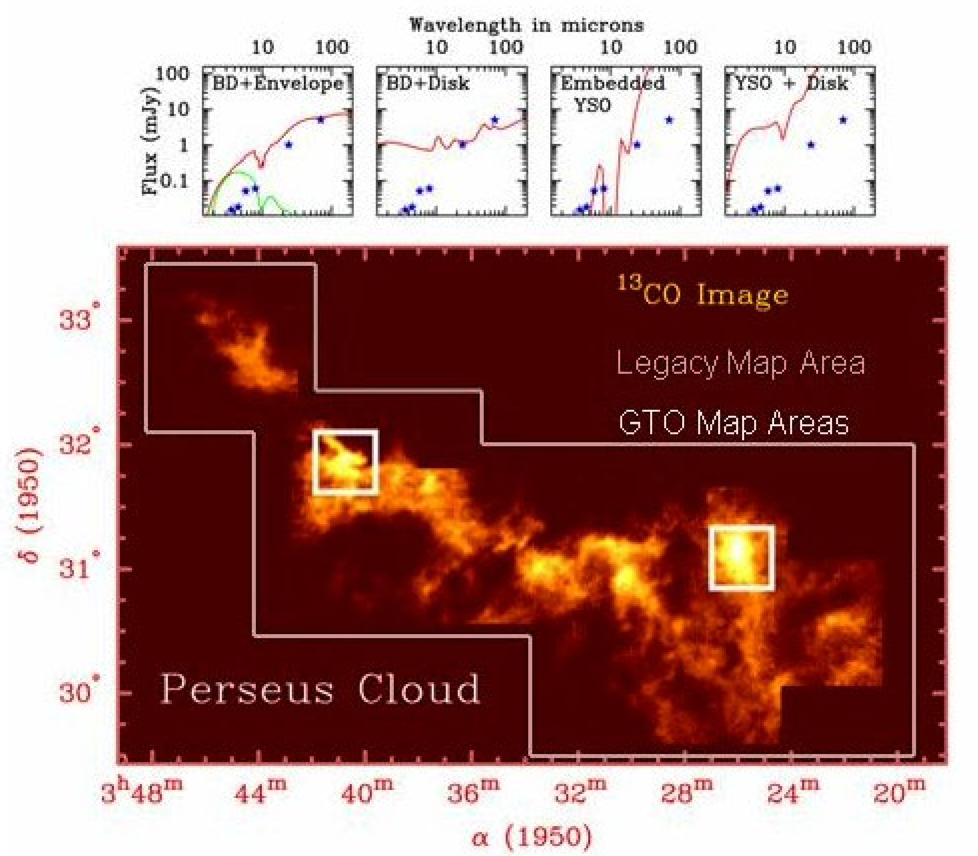


Figure 3. (Cores to Disks Legacy Team – N.Evans, PI)

The outline of planned SIRTF maps of the nearby Perseus molecular cloud complex overlayed on an existing CO image. The white squares show GTO observations, the area outlined in pink shows the planned coverage of the Legacy project. The small panels above show the sensitivity of SIRTF in the survey bands (blue stars) in the large area survey, compared to the expected brightness of brown dwarfs (with and without accompanying disk) and young stellar object (again with/without disk) at the distance of Perseus. Spectroscopic follow-on of sources found in the molecular cloud surveys such as this are part of the Legacy program and will form the basis of General Observer projects.

Planetary Debris Disks in Time

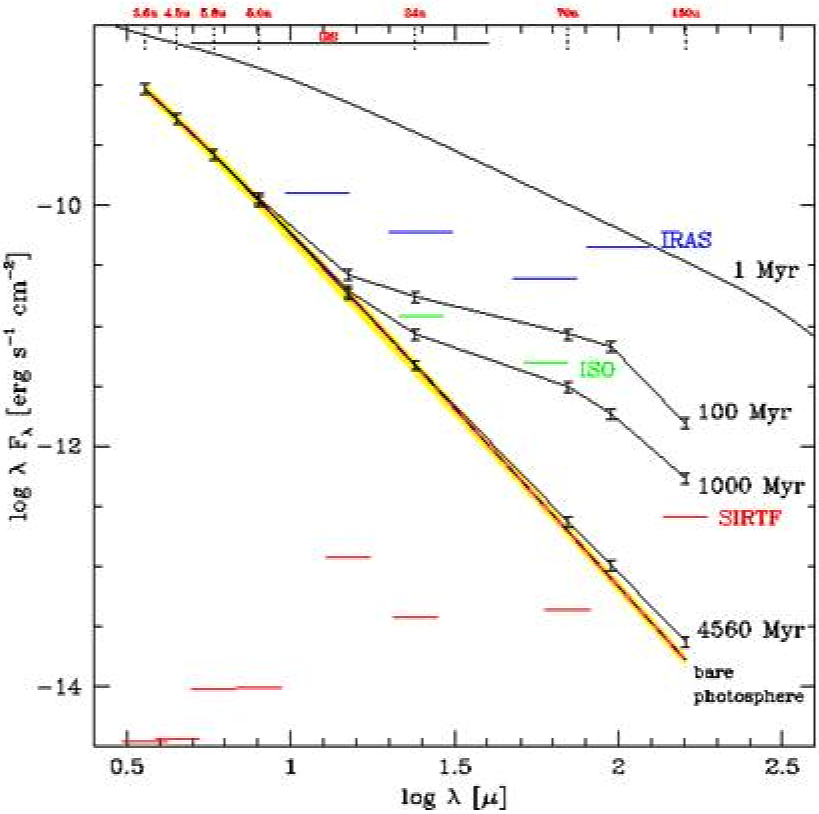


Figure 4. (Formation and Evolution of Planetary Systems Legacy Team – M.Meyer, PI) Plot showing the Spectra energy distribution vs. wavelength (in microns) for a solar mass star + planetary debris disk at a distance of ~30 pc as a function of age from the T Tauri stage through the solar system phase , compared to the 3_ sensitivities of SIRTF, the original infrared sky survey mission IRAS, and the European mission ISO. This illustrates that SIRTF will be able to detect far smaller infrared excesses that prior missions, and hence trace the evolution of debris disks to much greater ages. In addition to photometric observations, SIRTF spectroscopy can be used to probe the structure and composition of planetary debris disks, and imaging will directly reveal the structure in the closest debris disks.